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STANDARD POWER PLANT CHARACTERISTICS FOR ADVANCED NAVAL VEHICLE--ETC(U)
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LEVEL II

STANDARD POWER PLANT CHARACTERISTICS FOR ADVANCED NAVAL VEHICLES IN THE 1980 — 2000 TIME PERIOD.

for

David W. Taylor Naval Ship Research & Development Center

Bethesda, Maryland 20084

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This document has been prepared to provide a single set of standardized characteristics to describe the power plants expected to be available by the year 2000. It is proposed to use these standard data for all conceptual vehicle designs and evaluation studies in the ANVCE program. This standardization has been considered necessary in order to avoid the inconsistencies which may have resulted from otherwise independent extrapolations of technological trends. All extrapolations to the year 2000

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are based on technological trends which have been evident up to present date (1976) including both in-service, demonstrated performance and the results of design studies, experimental investigations and advanced-development programs. The projections have been made and justified essentially on the basis of Reference 1. Further justification data is presented as Appendix A to this document.

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1. INTRODUCTION

This document has been prepared to provide a single set of standardized characteristics to describe the power plants expected to be available by the year 2000. It is proposed to use these standard data for all conceptual vehicle designs and evaluation studies in the ANVCE program. This standardization has been considered necessary in order to avoid the inconsistencies which may have resulted from otherwise independent extrapolations of technological trends.

For convenience, all principal characteristics have been presented graphically as a function of required continuous shaft horsepower. In each case at least two curves are shown: one representing the characteristics of power plants expected to be available in quantity production by the year 2000 and the other curves, presented for comparison only, are applicable to the year 1970 and/or 1980, as indicated.

Characteristics for eight distinct types of power plant are presented, as listed in Table 1. Table 1 also identifies the parameters selected for power plant characterization along with an index for figure or page numbers where the data may be found within this document.

Wherever applicable, the data is presented for sea level, International Standard Atmospheric (ISA) conditions, (59°F, 15°C, etc). Where curves are shown as a function of maximum continuous power this rating has been interpreted as the maximum power that can be sustained continuously* within acceptable time between overhauls or with normal inspection intervals and maintenance cycles. Note that some engine manufacturers distinguish between maximum continuous power and continuous power ratings where the maximum continuous rating is only applicable to, say, 4 hours of continuous operation. In such cases this continuous power rating is equivalent to the maximum continuous rating defined herein.

In all cases it will be assumed that maximum intermittent (reserve, stand-by or take-off) ratings are 15% greater than maximum continuous ratings.

All extrapolations to the year 2000 are based on technological trends which have been evident up to present date (1976) including both in-service, demonstrated performance and the results of design studies, experimental investigations and advanced-development programs. The projections have been made and justified essentially on the basis of Reference 1. Further justification data is presented as Appendix A to this document.

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* Power available for propulsion and accessory drives etc. with engine installed having specific inlet and exhaust duct pressure losses, and does not include transmission power losses.

Table 1. Power Plant Types, Characteristic Parameters and Index to Page and Figure Numbers.

POWER PLANT TYPE	SPECIFIC WEIGHT LB/SHP	ON-DESIGN OR MAX.CONT.SFC LB/HP. HR.	PARTIAL POWER SFC	POWER DENSITY SHP/FT^3	SPECIFIC COST $/SHP
Reciprocating Marine Diesels	Fig. 1	Fig. 3	Fig. 4	Fig. 6	Fig. 7
Rotary Marine Diesels	Fig. 1	Fig. 3	Fig. 4	Fig. 6	Fig. 7
Open-Cycle Marine Gas-Turbines	Fig. 1	Fig. 3	Figs. 4&5	Fig. 6	Fig. 7
Closed-Cycle Marine Gas-Turbines	Fig. 1	Fig. 3	Fig. 4	Fig. 6	Fig. 7
Regenerative Cycle Marine Gas-Turbines	Fig. 1	Fig. 3	Pg. 3	Fig. 6	Fig. 7
Aircraft Gas-Turbines	Fig. 1	Fig. 3	Fig. 4	Fig. 6	Fig. 7
Marine Nuclear Power Plants	Fig. 2	Pg. 3	Pg. 3	Pg. 5	Pg. 5
Free-Piston Engines	Pg. 3	Pg. 3	Pg. 3	Pg. 5	Pg. 5

2. CHARACTERISTIC STANDARDS

2.1 Specific Weight

Figures 1 and 2 present dry-engine specific weights (weight per maximum continuous horsepower) for various power plants as a function of maximum continuous power rating. All engine weights used are complete, dry (no fuel and lubricant) engine weights with standard accessories, and minimum inlet and exhaust ducts, excluding gear boxes and transmission. (i.e. WBS group 230) In the case of the nuclear power plants the weights include all power plant and reactor components and shielding, controls, auxiliaries and reduction gearings up to the connection to transmission shafting. (i.e. WBS group 210 and 230).

Free-piston engines, not shown in Figure 1, are projected to have specific weights of 0.7 lb/shp (0.313 Kg/mshp) for maximum continuous power in the range 1000 to 10,000 shp (Reference 1).

2.2 On-Design Specific Fuel Consumption (SFC)

On-design SFC, or SFC based on maximum continuous power operation, is shown in Figure 3. ISA sea level conditions are again assumed. Corrections necessary for other environmental operating conditions must be determined and justified independently. Fuel consumption or fuel cost for nuclear power plants must also be determined independently.

The specific fuel consumption of free-piston engines, projected for the year 2000 in the power range 1000 to 10,000 maximum continuous shp, may be taken as 0.24 lb/shp-hr (0.107 Kg/mshp-hr) (Reference 1).

2.3 Partial Power Specific Fuel Consumption

Figure 4 shows the ratio, (R), of partial power SFC to maximum continuous SFC as a function of percent maximum continuous power. For open-cycle gas-turbines it has also been necessary to show this relationship as a function of actual maximum continuous power. In this case, Figure 5 is provided to assist in interpolating for specific power requirements.

Since, for specific engines, SFC is a function of both shaft speed and percent horsepower, a $P \alpha N^3$ propulsor power law has been assumed throughout.

The off-design performance of free-piston engines will be assumed to follow a trend equivalent to that of the diesel engine. The off-design performance of regenerative cycle marine gas turbines will be assumed to follow a trend equivalent to that of the open cycle marine gas turbine.

Note that the curves plotted in Figures 4 and 5 are those projected for engines in quantity production by the year 1980. For engines in quantity production by the year 2000 apply the following corrections: -

Assume $(R)_{2000} = [(R)_{1980} - 1.0]\ 0.7 + 1.0$ for open-cycle gas-turbine engines

and $(R)_{2000} = (R)_{1980} - (100 - x)/1800$ for diesel and closed-cycle gas-turbine engines

where $(R)_{1980}$ is the SFC ratio projected for 1980

and $(R)_{2000}$ is the SFC ratio projected for the year 2000.

2.4 Power Density

Power density, in terms of maximum continuous power per cubic volume of an equivalent rectangular box, is shown as a function of required power in Figure 6. It is assumed that in all cases the volume does not include the volume required for inlet and exhaust ducting even if some ducting may normally be considered as an integral part of the engine.

Difficulty was experienced in developing a consistent power density trend for marine gas-turbine engines. Up to 4300 shp, present day maximum power densities for marine gas-turbines can be represented by the AVCO/Lycoming TF series* of production and projected engines. For power in excess of 4300 shp power density trends of marine gas-turbines have been influenced less by volume minimization incentives. By the year 2000, however, a significant improvement of large-engine power density could (and will be assumed to) be made possible with a density trend midway between that of current day aircraft and marine gas-turbine engines. The curve to be used is that which is labeled "open and closed-cycle marine gas-turbine" shown in Figure 6.

For the purpose of marine gas-turbine power plant installation layout the following dimensional proportions will be assumed: -

Max. Cont. Power	$\leq$ 4300 shp	> 4300 shp
$\frac{\text{LENGTH}}{\text{WIDTH}} \left(\frac{L}{W}\right) =$	1.7	3.0
$\frac{\text{DEPTH}}{\text{WIDTH}} \left(\frac{D}{W}\right) =$	1.3	1.0

* Derived from the T53 and T55 helicopter engines for which volume minimization was a particularly high incentive.

where $$W = \left[\frac{(\text{Max. Cont. Power})}{\left(\frac{L}{W}\right)\left(\frac{D}{W}\right)\left(\text{Power Density}\right)} \right]^{1/3}$$

Note that the equivalent rectangular box, defined above, does not include the additional special requirements for accessories and maintenance etc.

The proportions, defined above, can also be assumed to apply to closed-cycle and regenerative-cycle gas-turbine engines.

For reciprocating marine diesels assume: -

$$\left(\frac{L}{W}\right) = 2.5 \quad \text{and} \quad \left(\frac{D}{W}\right) = 1.2$$

For rotary marine diesels assume: -

$$\left(\frac{L}{W}\right) = 1.8 \quad \text{and} \quad \left(\frac{D}{W}\right) = 1.0$$

For free piston engines assume a constant power density of 70 shp/ft^3 (2496.5 mshp/m^3) and proportions the same as reciprocating marine diesels. The volume and proportions of nuclear propulsion plant installations must be determined and justified independently.

2.5 Specific Cost

The cost data used in the preparation of Figure 7 came from References 1 and 2. The specific cost of free-piston engines (not shown in Figure 7) may be assumed equal to that of reciprocating marine diesel engines. The cost of a nuclear power plant installation must be determined and justified independently.

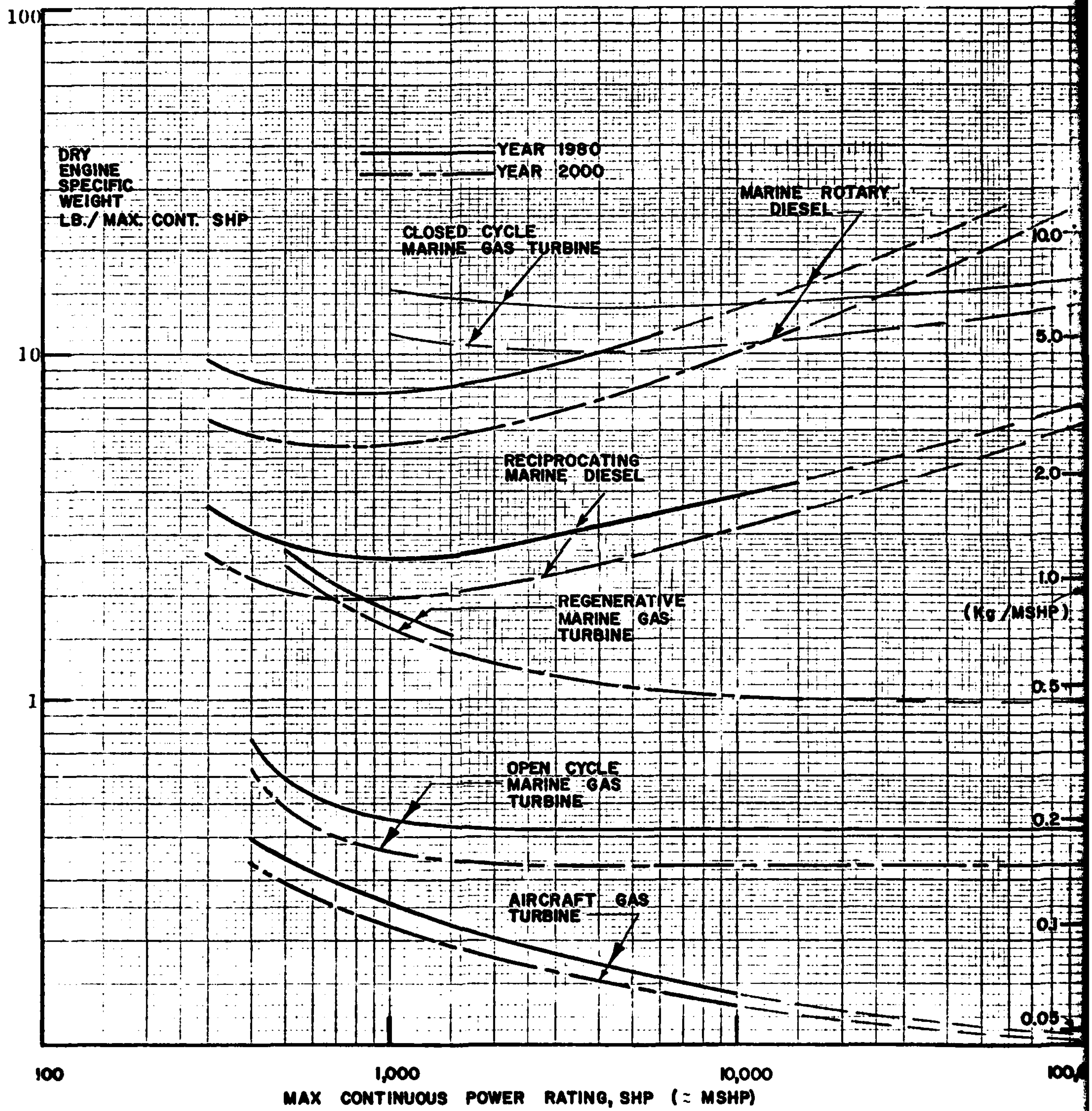


Figure 1. Specific Weight Projected for Various Engines in Quantity Production by the Year Shown.

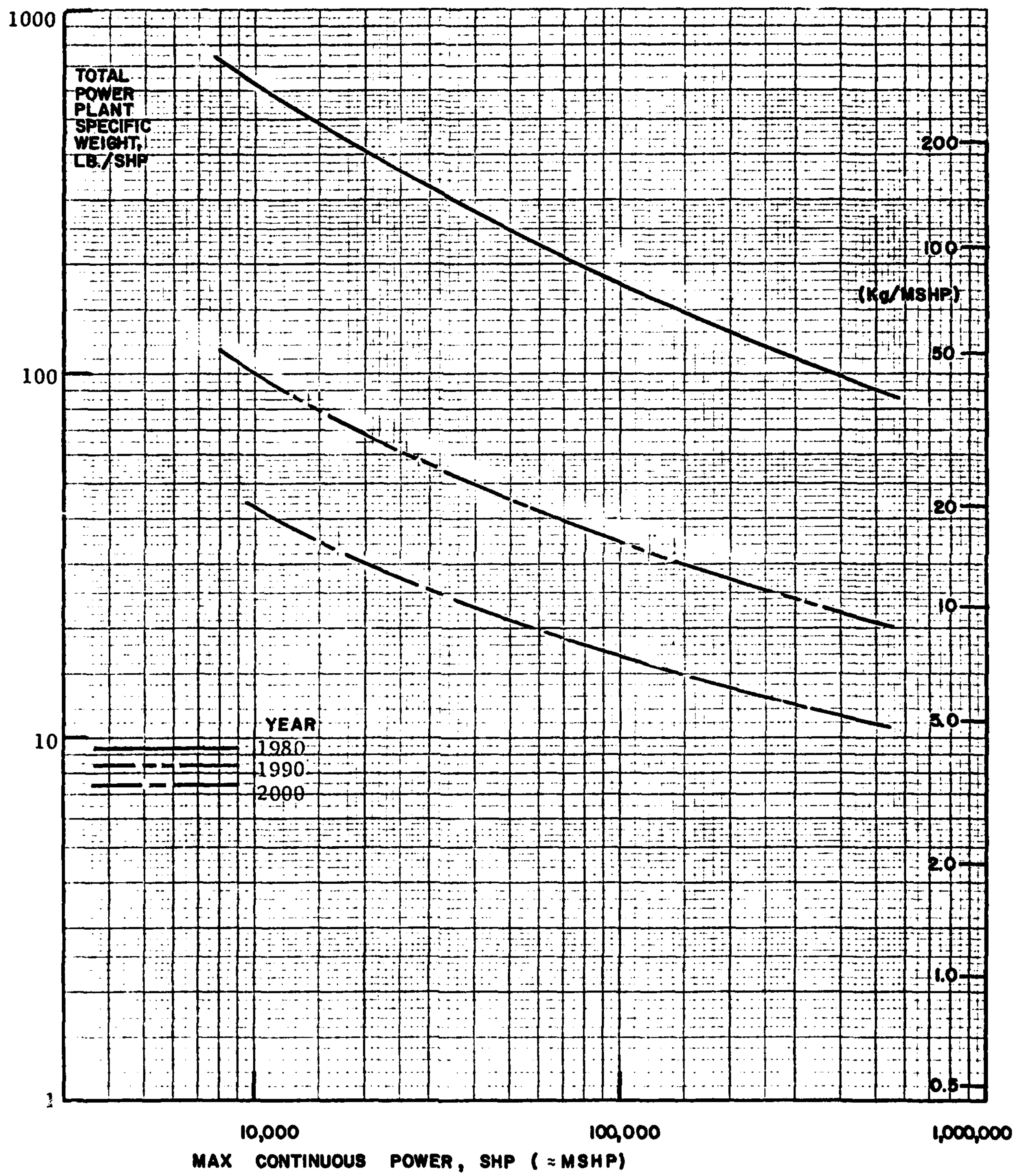


Figure 2. Specific Weight of Marine Nuclear Power Plants.

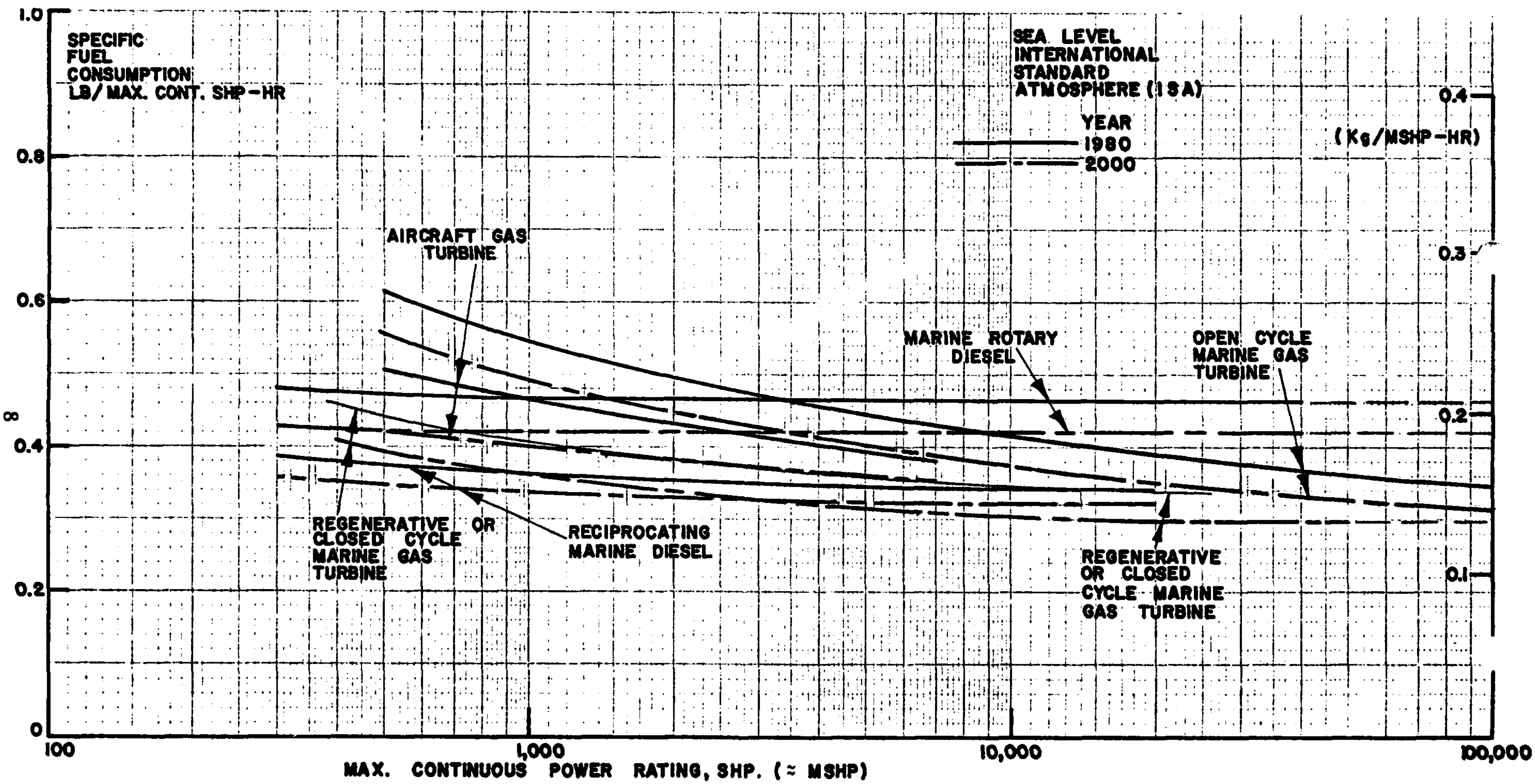
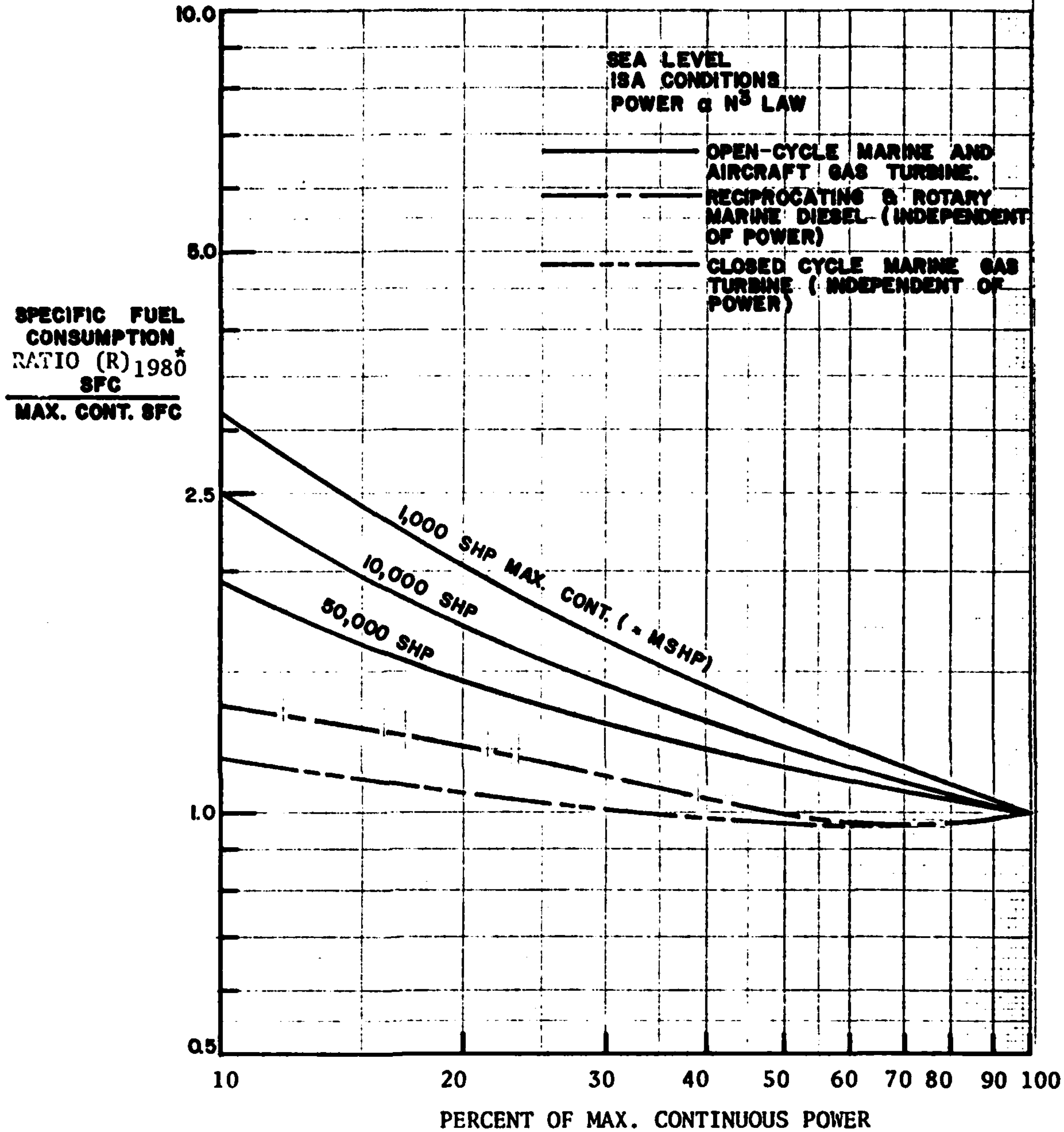


Figure 3. Specific Fuel Consumption Projected for Various Engines in Quantity Production by the Year Shown.



* For Engines in Quantity Production by the year 2000

Assume $(R)_{2000} = [(R)_{1980} - 1.0]\ 0.7 + 1.0$ for open-cycle gas-turbine engines

and $(R)_{2000} = (R)_{1980} - (100 - x)/1800$ for diesel and closed-cycle gas-turbine engines.

Figure 4. Specific Fuel Consumption Ratio for 1980 Gas Turbines and Diesel Engines During Partial Power Operation.

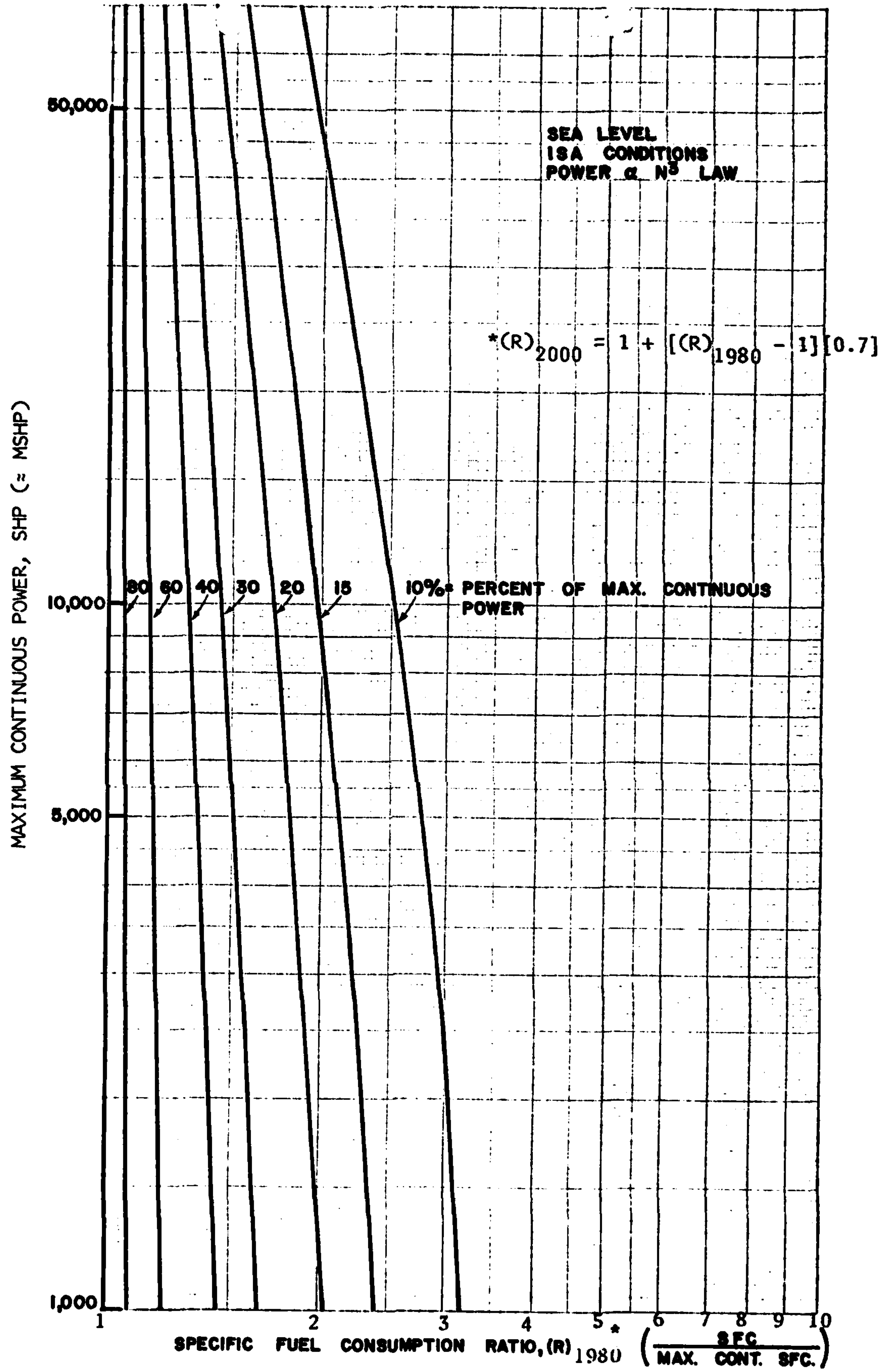


Figure 5. Specific Fuel Consumption Ratio for Marine Gas Turbines as a Function of Maximum Continuous Power and Percent Partial Power.

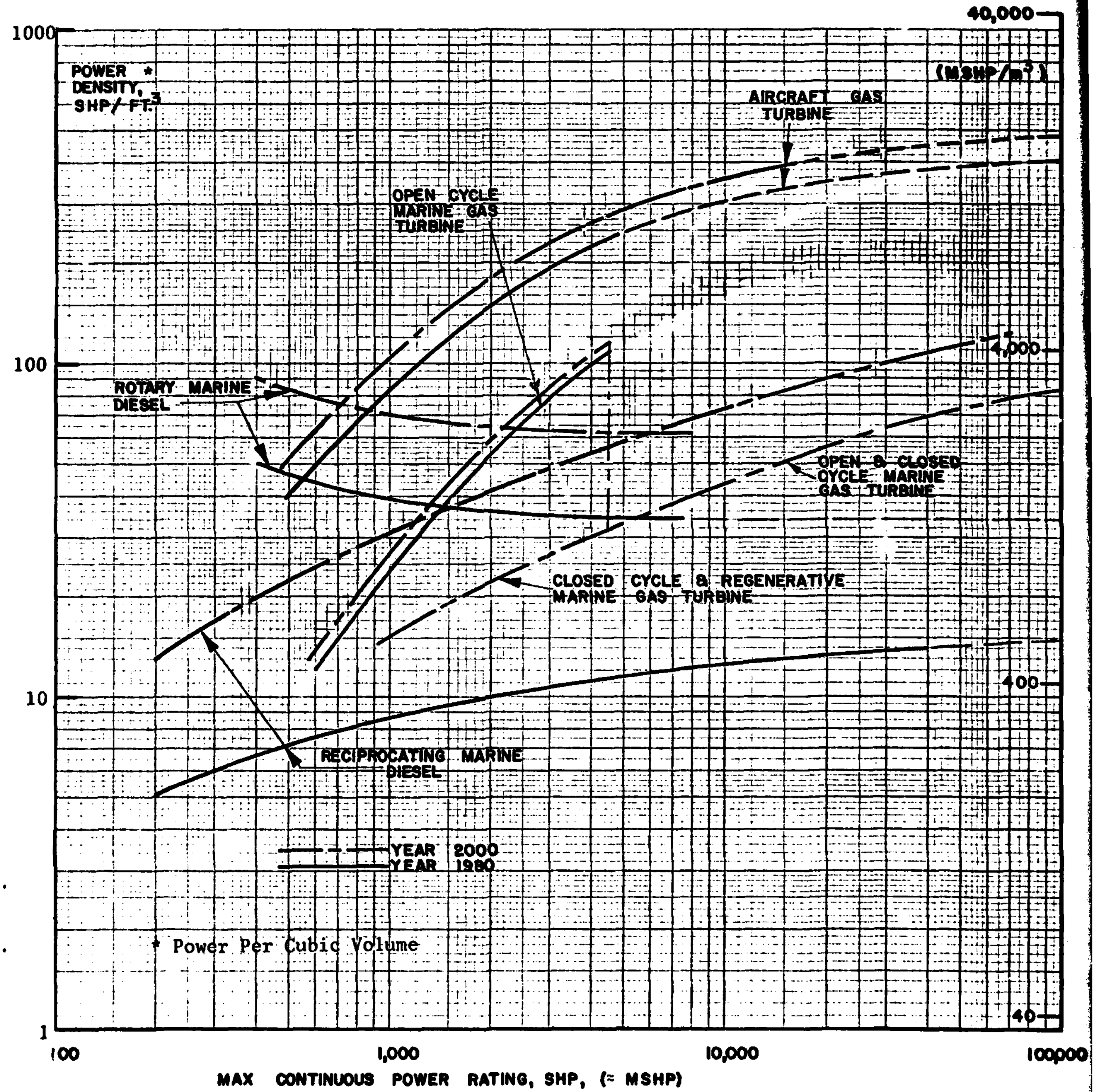


Figure 6. Power Density (Power/Volume) vs. Power, Projected for Various Engines in Quantity Production by the Year Shown.

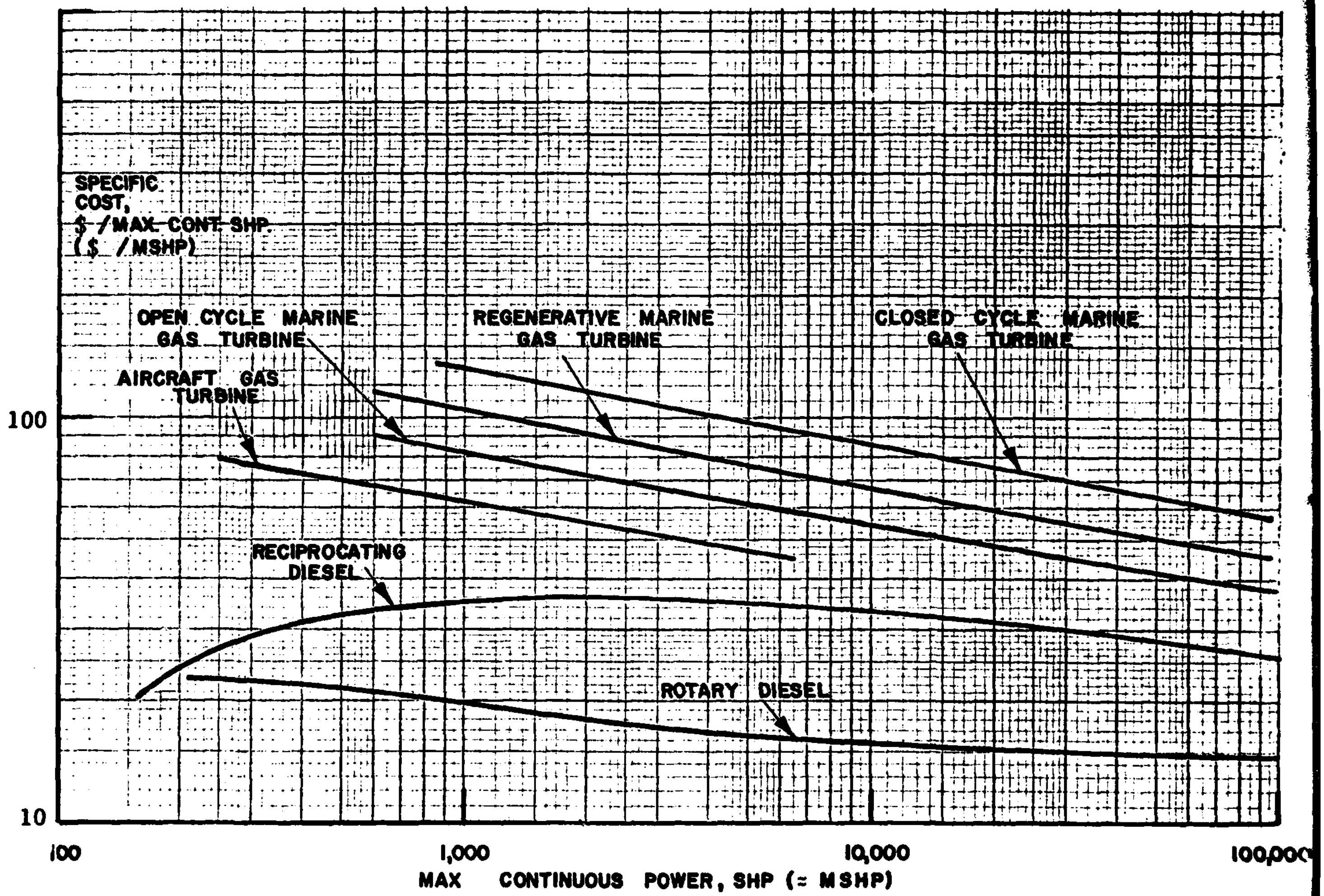


Figure 7. Relative Procurement Cost of Various Marine Engines.

REFERENCES

1. "A Review of Power Plants Likely to be Available for Advanced Naval Vehicles in the 1980-2000 Time Period", Payne, Inc. Working Paper No. 181-7, (March 1976).

2. Blose, J.F. "Amphibious Assault Landing Craft Program (S14-17) Prior Craft Review, Vol. 3, Machinery Systems Analysis (U)", NSRDC Report No. C2428, (April 1968).

APPENDIX A

EXTRAPOLATION OF

POWER PLANT CHARACTERISTICS TO THE YEAR 2000

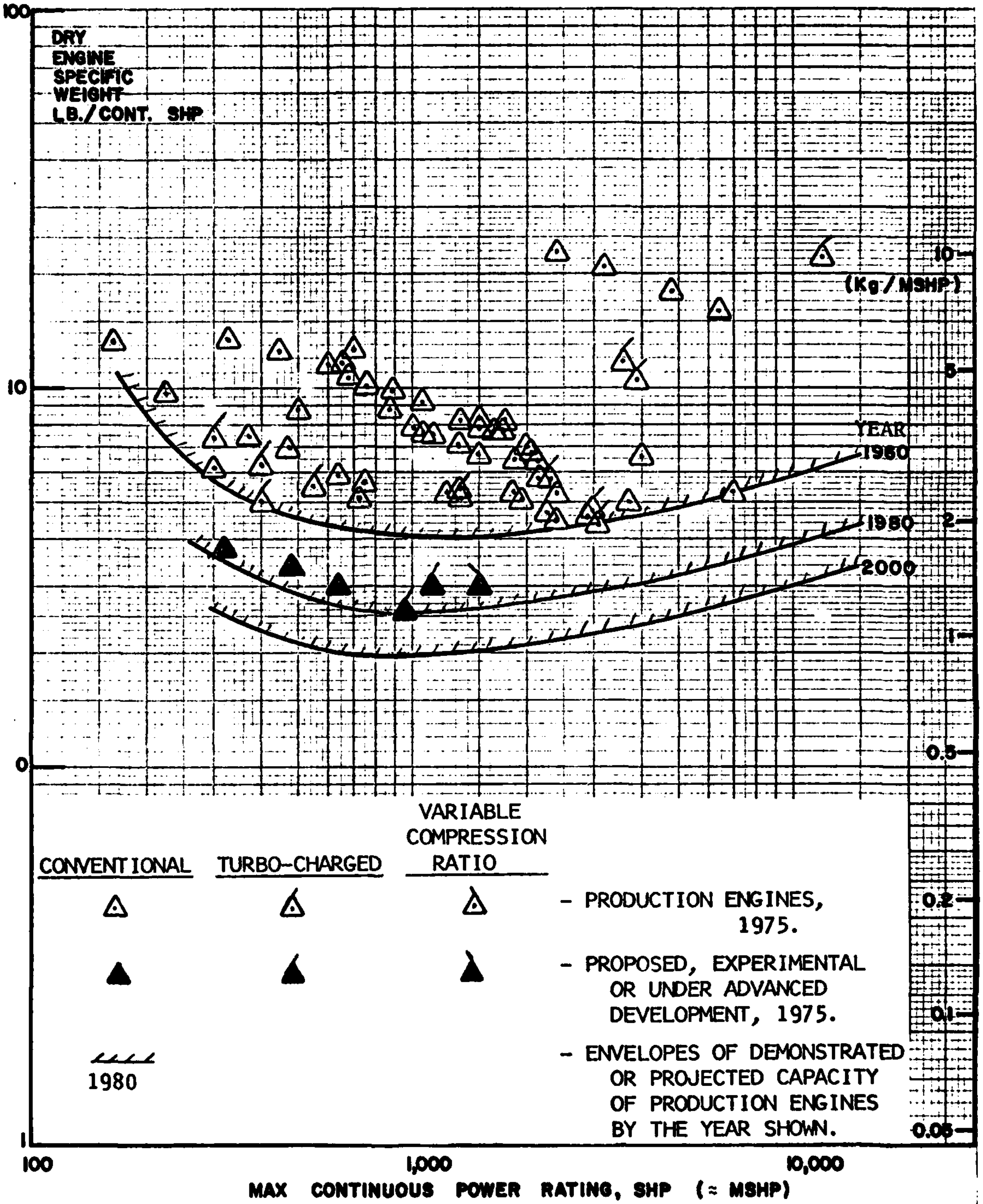


Figure A-1. Diesel Engine Specific Weight Trends with Respect to Continuous Power Rating and Year of Quantity Production.

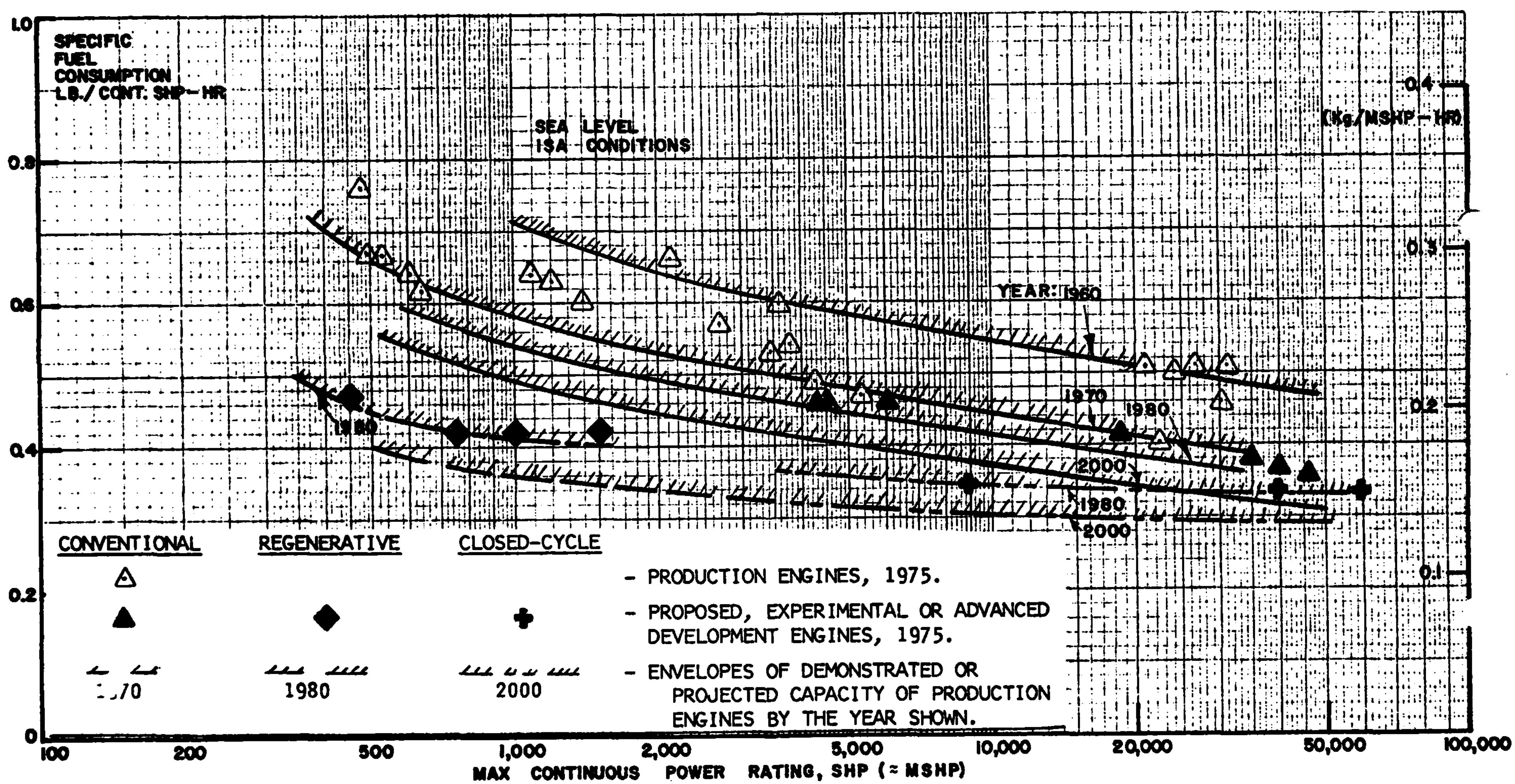


Figure A-2. Marine Gas Turbine Specific Fuel Consumption Trends with Respect to Continuous Power Rating and Year of Quantity Production.

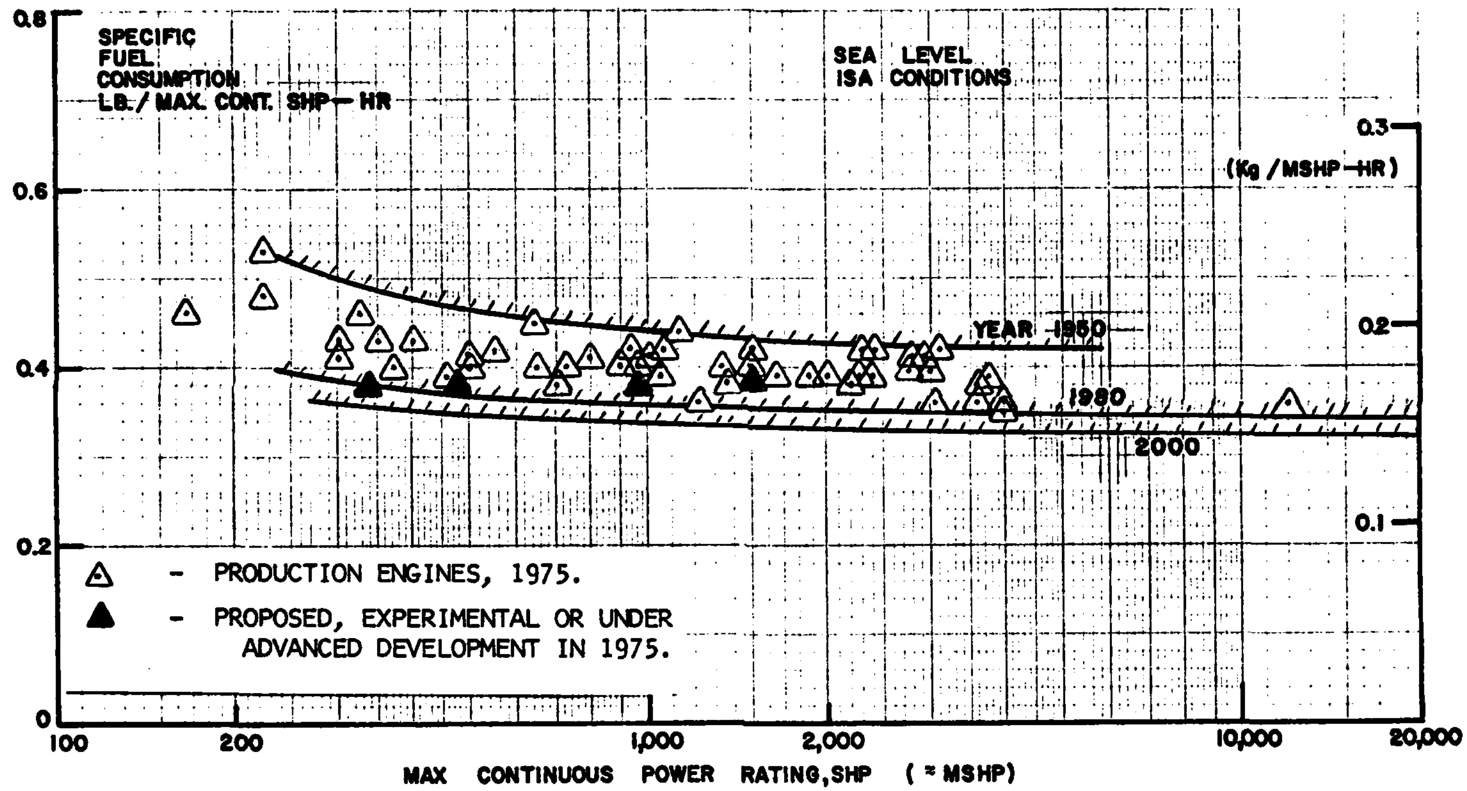


Figure A-3. Diesel Engine Specific Fuel Consumption Trends with Respect to Continuous Power Rating and Year of Quantity Production.

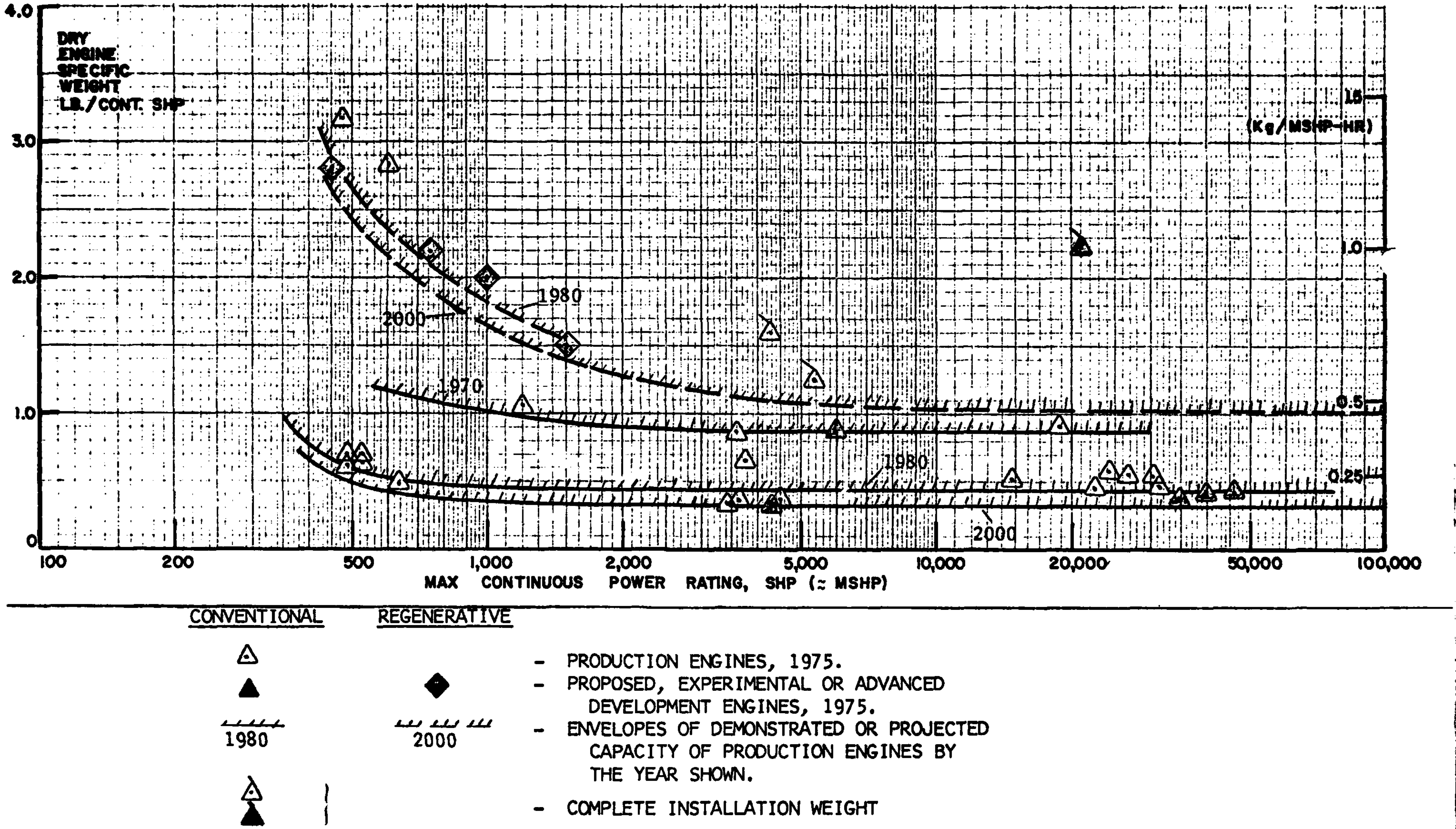


Figure A-4. Marine Gas Turbine Specific Weight Trends with Respect to Continuous Power Rating and Year of Quantity Production.

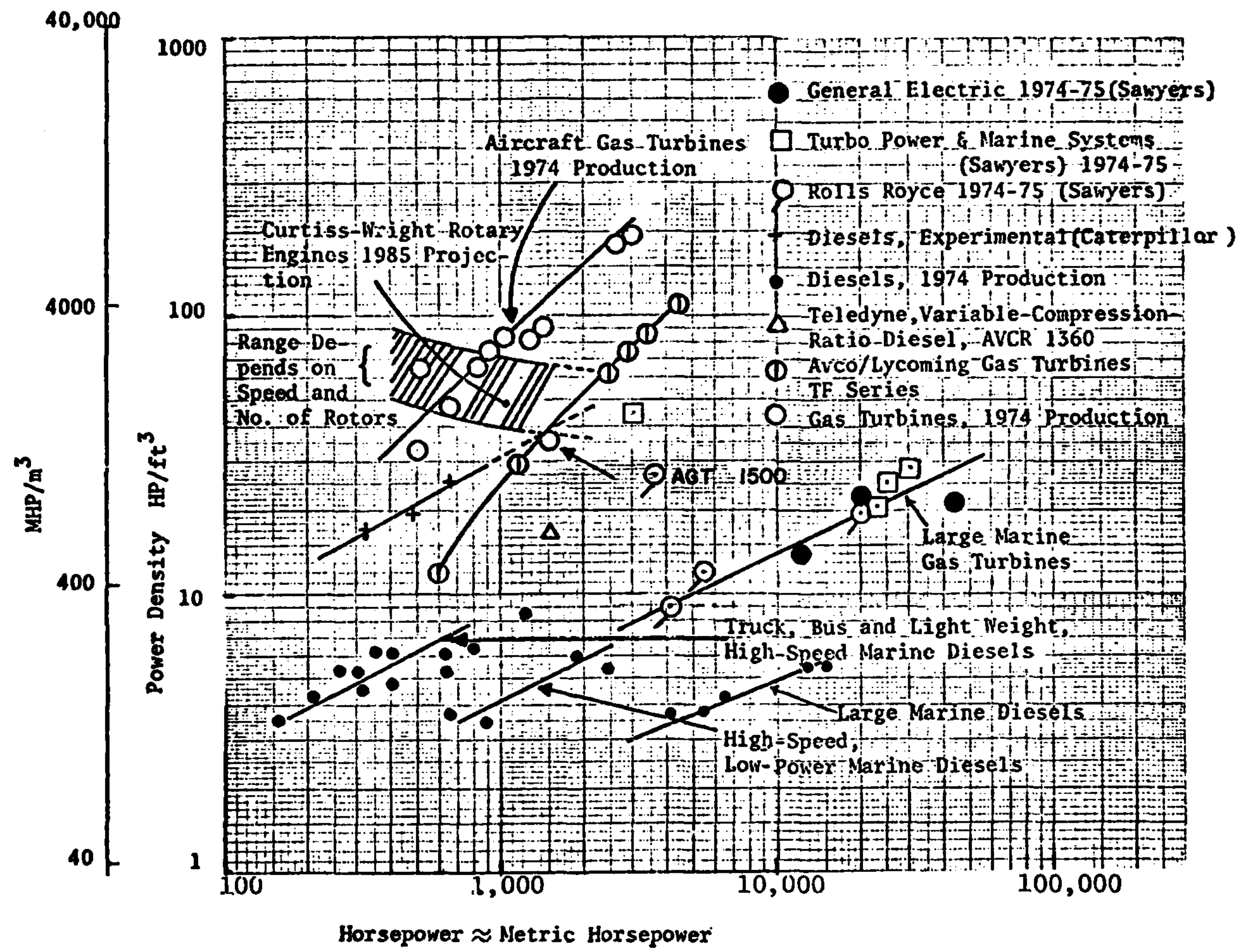


Figure A-5. Power Density (power/volume*) vs Power for Various Engine Types.

* Volume of Equivalent Rectangular Box.

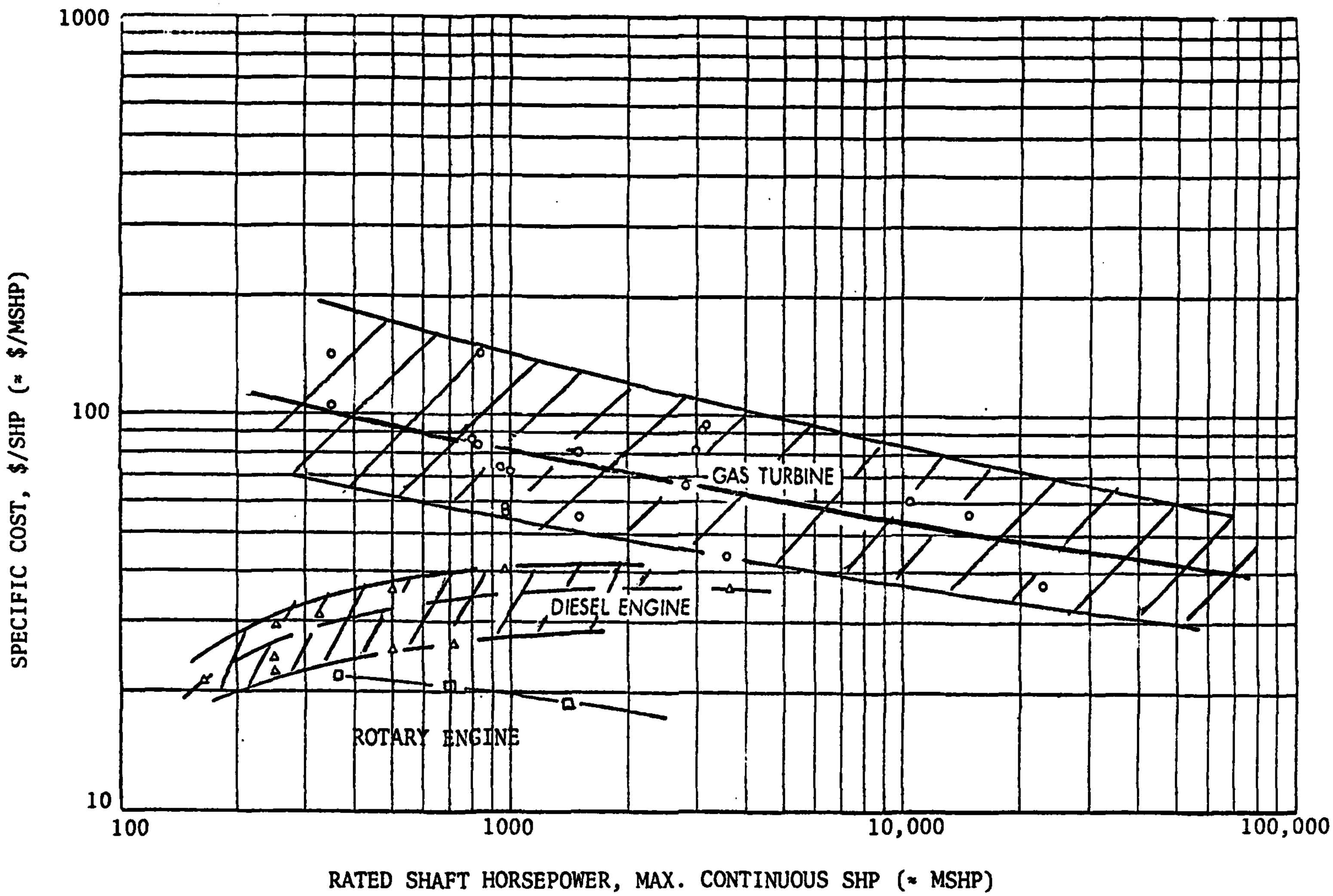


Figure A-6. Engine Cost Versus Rated Power Output for Gas Turbine,Diesel and Rotary Engines.